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SEASONAL VARIATION OF PHYTOPLANKTON COMMUNITY IN THE NORTHERN OF OMAN SEA (PART OF IRANIAN WATERS)

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ABSTRACT

The present study, which deals with the phytoplankton community, was performed in 2010 during pre- and post-monsoon seasons at the northern part of the Oman Sea. Samples were collected from the Strait of Hormuz to Gwadar using Rosettle bottle sampler. Results showed differences among phytoplankton communities. Revealed that in the pre-monsoon season, Dinophyceae was the most abundant group (91.74%), followed by Bacillariophyceae (5.90%), Cyanophyceae (1.87%), and other groups (0.49%). Meanwhile, in the post-monsoon season, Bacillariophyceae was dominant (86.36%), followed by Dinophyceae (13.15%), Cyanophyceae (0.07%), and other groups (0.42%). During the pre-monsoon season, 150 species were observed, including 56 species of Bacillariophyceae, 87 species of Dinophyceae, 4 species of Cyanophyceae, 2 species of Dicthyochophyceae and 1 species of Silicoflagellate. In the post-monsoon season, 139 species were observed, including Bacillariophyceae (65), Dinophyceae (69), Cyanophyceae (4), Dicthyochophyceae (2) and Silicoflagellate (1).

Therefore, a higher number of phytoplankton taxa were associated with pre-monsoon season. Bray–Curtis similarity index showed similarities of species composition between the two seasons at 36.26% level. ANOSIM Analysis showed a difference in species composition between the two seasons (global R=0.36). The results of this study showed that the monsoon wind has a significant effect on the phytoplankton community.

KEYWORDS: Pre-Monsoon, Post-Monsoon, Phytoplankton, ANOSIM, Bray-Curtis, Oman Sea, Strait of Hormuz

INTRODUCTION

Phytoplankton are major producers in aquatic ecosystems (Angspanich and Rakkheaw, 1997). Studies on the abundance and structure of the phytoplankton community are important in understanding the health of an ecosystem. Phytoplankton, as the basis of the trophic chain, forms the biological community that regulates the food chain; scientific research focuses on the food chain when a management plan is needed or when an evaluation of ecosystem health is required (Monbet, 1992). The Oman Sea is one of the most important waterways in the world. It also harbors one of the most important marine ecosystems. Species composition and seasonal variation in phytoplankton abundance have not been completely studied in the north of Oman Sea. This area is strongly influenced by monsoon wind, and the changes associated with the onset of the monsoon have marked effects on the phytoplankton community, food web, and food production. The objective of this study is to prove the effects of seasonal patterns on phytoplankton succession, as well as variation and abundance of species.

MATERIALS AND METHODS

Study Area

This study was conducted at the northern part of the Oman Sea (including parts of Iranian waters) from the Strait of Hormuz to Gwadar, which covers the whole Iranian waters. The study area was divided into 10 transects from west to east (T1–T10). The sampling period consisted of the pre- and post-monsoon seasons in 2010.

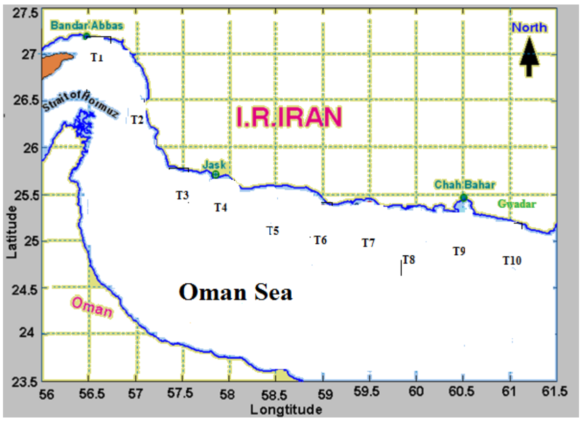

Figure 1: Study Area

Sampling

A Rosettle bottle sampler was used for plankton sampling, and three triplicates were obtained from each site.

Laboratory Analysis

Laboratory methods for phytoplankton analysis were divided into several steps (Wendy, 1999, Mitra *et al*., 2004, Suthers and Rissik, 2009). Samples were maintained for 7 to 10 days, allowing phytoplankton cells to settle and sink at the bottom for sedimentation. After sedimentation, surface water was removed without disturbing the bottom layer. The remaining substance was mixed to avoid cell clumping. Consequently, 1 ml sample was obtained and placed onto a Sedgwick–Rafter cell counter.

The total number of phytoplankton present in one l water sample was calculated using the formula

N= (n x v) / V

where N = total number of phytoplankton cells in 1 L water (cells/l); n = average number of phytoplankton cells in 1 ml plankton sample; v = volume of plankton concentrate (ml); and V = volume of total water filtered (L). Taxonomic guides and descriptions proposed by previous studies (Newell and Newel, 1963, Tomas *et al*., 1996, Horner, 2003, AL-Kandari *et al*., 2009, Hoppenrath et al., 2009, Al-Yamani, 2009, Al-Yamani and Saburova, 2010) were adopted.

Data Analysis

A one-way ANOVA Kruskal–Wallis non-parametric test was used to determine the significant abundance between the two seasons. To compare phytoplankton communities during the two seasons, non-parametric cluster analysis was used in accordance with the Bray–Curtis similarity index. The Bray–Curtis similarity index determines percentage similarity between two seasons. Significance level and sources of differences were tested using the analysis of similarity (ANOSIM) and similarity percentage (SIMPER) program of the Plymouth Routines in Multivariate Ecological Research (Primer software). ANOSIM demonstrated difference in phytoplankton composition between the two seasons, in accordance with the R global interpretation. R is scaled from –1 to +1. Groups are considered significantly different when

the R value is greater than zero. R statistics also indicates the degree of difference between the two groups, (Clarke and Warwick, 1994)**.**

RESULTS

In 2010, 186 taxa were identified, comprising 79 Bacillariophyceae, 100 Dinophyceae, 4 Cyanophyceae, 2 Dicthyochophyceae, and 1 Sillicoflagellate**.** The relative abundance (%) of different phytoplankton groups are as follows: Bacillariophyceae 46.95%, Dinophyceae 51.64%, Cyanophyceae 0.95%, and other groups 0.46%. During the same year, the dominant species were *Nitzschia seriata*, *Chaetoceros dichaeta*, *Lolioma elongatum*, *Leptocylindrus danicus*, *Chaetoceros atlanticum*, *Chaetoceros didymus*, *Nitzschia longissima*, *Nitzschia sigma*, *Navicula membrane*, *Cochlodinium polykrikoides*, *Prorocentrum belizeanum*, *Prorocentrum rocentrum*, *Heteraulacus polydricus*, *Gymnodinium spirale*, and *phormidium.*

During the pre-monsoon season, 150 species were observed, comprising 56 species of Bacillariophyceae, followed by 87 species of Dinophyceae, 4 species of Cyanophyceae, 2 species of Dicthyochophyceae, and 1 species of Silicoflagellate. Meanwhile, in the post-monsoon season, 139 species were observed, i.e., Bacillariophyceae (65), Dinophyceae (69), Cyanophyceae (4), Dicthyochophyceae (2), and Silicoflagellate (1) (Table 1).

The major species were *Nitzschia sigma*, *Nitzschia pungens*, *Nitzschia lorenziana*, *Pesudonitzschia fraudulenta*, *Coscinodiscus granii*, *Coscinodiscus radiatus*, *Diploneis splendida*, *Cyclotella striata*, *Cochlodinium polykrikoides*, *Dipolosialis sp.*, *Heteraulacus polydricus*, *Prorocentrum rocentrum*, *Prorocentrum sigmoides*, *Prorocentrum gracile*, *Prorocentrum belizeanum*, *Gymnodinium spirale*, *Protoperidinium conicoides*, *Phormidium sp.*, and Sillicoflagellate. Members of class Bacillariophyceae, such as *Nitzschia seriata*, *Chaetoceros dichaeta*, *Lioloma elengatum*, *Leptocylindrus danicus*, *Chaetoceros atlanticum*, *Chaetoceros didymus*, *Coscinodiscus radiatus*, *Nitzschia closterium*, *Navicula membrane*, *Navicula acutum*, *Eucampia zoodiacus*, *Navicula elegans*, *Lauderia annulata*, *Hemiaulus indicus*, *Cochlodinium polykrikoides*, *Noctiluca scintillans*, *Protoperidinium steinii*, *Prorocentrum gracile*, *Prorocentrum lima*, *Ceratium furca* and *Ceratium fusus*, were more abundant compared with other species. In addition, *Dictyocha fibula*, which belongs to class Dicthyochophyceae, was observed in the post-monsoon season.

Table 1: Number of Phytoplankton Taxa during Pre and Post-Monsoon Season

	Season	
Group	**Pre-Monsoon**	**Post -Monsoon**
Bacillariophyceae	56	65
Dinophyceae	87	69
Cyanophyceae	4	2
Dicthyochophyceae	2	2
Silicoflagellate	1	1

Comparison of the different phytoplankton groups during the two seasons showed that during the pre-monsoon season, Dinophyceae was the most abundant (91.74%), followed by Bacillariophyceae (5.90%), Cyanophyceae (1.87%), and other groups (0.49%). During the post-monsoon season, Bacillariophyceae was dominant (86.36%), followed by Dinophyceae (13.15%), Cyanophyceae (0.07%), and other groups (0.42%) (Figure 2).

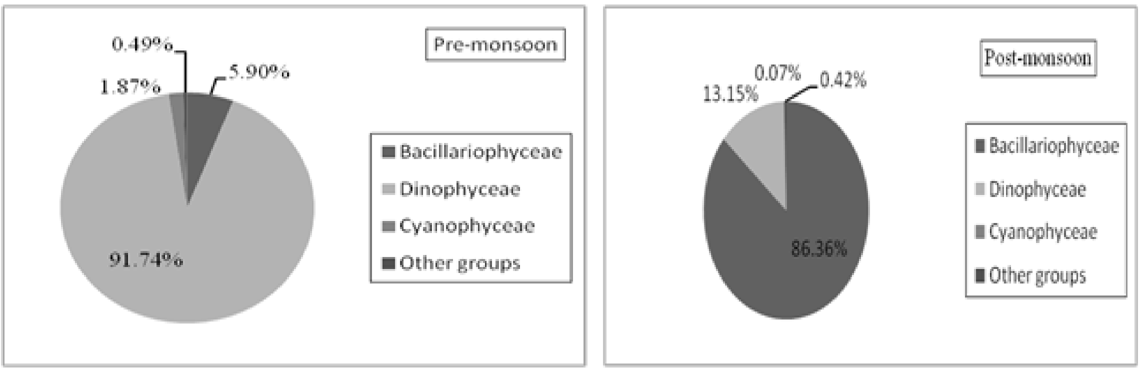

Figure 2: Relative Abundance (%) of Different Groups of Phytoplankton during the Pre-Monsoon and Post-Monsoon Season

Bray–Curtis similarity showed species composition similarity between the two seasons at 36.26% level (Figure 3).

Figure 3: Bray- Curtis Similarity Dendrogram between Pre and Post-Monsoon Season

Difference in species composition was noted between the pre- and post-monsoon seasons, according to ANOSIM results (R = 0.36). The most dominant species responsible for the difference between the two seasons were identified using SIMPER (Table 2). *Heteraulacus polyedricus*, *Nitzschia pungens*, *Prorocentrum triestnum*, *Prorocentrum sigmoides*, and *Prorocentrum rocentrum* were only found in the pre-monsoon season. However, some species, such as *Cochlodinium polykrikoides*, *Gymnodinium spirale*, *Protoperidinium conicoides*, *Prorocentrum belizeanum*, *Phormidium sp.* and *Nitzschia sigma*, were more abundant in the pre-monsoon season. Meanwhile, *Chaetoceros dichaeta*, *Lioloma elengatum*, *Leptocylindrus danicus*, *Nitzschia closterium*, *Chaetoceros atlanticum*, *Amphisolenia palmata*, *Rhizosolenia imbricata*, *Chaetoceros didymus*, *and Guinardia flaccida* were only present in the post-monsoon season. The statistical non-parametric Kruskal–Wallis test showed significant difference in the abundance of different phytoplankton groups with regard to season ($P<0.05$). The post-monsoon season showed higher abundance.

Table 2: Major Species, Contributing to the Average Dissimilarities between Samples during Pre and Post-Monsoon Season, as Determined by SIMPLER Analysis

	Group					
Group Pre and Post-Monsoon	**Pre-Monsoon**	**Post-Monsoon**				
Species	**Ave.Abun**	**Ave.Abun**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Cochlodinium polykriokoides	4943.82	578.14	29.11	1.09	34.06	34.06
Lioloma elongatum	o.97	913.24	8.01	0.68	9.34	43.43
Nitzschia seriata	14.74	1512.79	3.16	0.31	3.7	47.13
Chaetoceros dichaeta	0	13.05	2.82	0.35	3.3	50.42
Prorocentrum belizeanum	235.81	5.05	2.56	0.37	2.99	53.42

Table 2: Contd.,

Coscinodiscus radiatus	18.55	104.34	2.36	0.57	2.76	56.17
Leptocylindrus danicus	0	433.6	1.82	0.23	2.13	58.3
Navicula membrane	1.88	110.16	1.45	0.27	1.7	60
Prorocentrum rocentrum	148.06	0	1.27	0.24	1.48	61.49
prorocentrum gracile	46.33	30.79	1.17	0.49	1.37	62.86
Phormidium sp.	102.49	0.11	1.06	0.21	1.24	65.37
Navicula acutum	21.3	58.62	1.02	0.42	1.19	66.56
Gymnodinium spirale	60.23	2.29	1	0.23	1.17	67.73
Gyrosigma acuminatum	9.71	32.23	0.83	0.36	0.97	68.7
Noctiluca scientalis	8.52	24.65	0.81	0.33	0.95	69.65
Protoperidinium conicoides	63.62	0.1	0.76	0.36	0.89	70.55
Nitzschia sigma	150.72	0.43	0.76	0.13	0.89	71.4
Diplopsalis sp.	42.71	8.33	0.74	0.21	0.86	72.3
Planktoniella sol	1.64	35.21	0.73	0.45	0.85	73.15
prorocentrum triestnum	42.44	0	0.73	0.22	0.85	74
Heteraulacus polyedricus	69.99	0	0.72	0.15	0.84	78.85
Protoperidinium steinii	5.85	22.1	0.68	0.36	0.8	75.65
Navicula elegans	0.99	38.68	0.68	0.34	0.8	76.45
Eucampia zoodiscus	3.56	59.56	0.63	0.27	0.73	77.18
Nitzschia closterium	0	133.14	0.58	0.21	0.68	77.86
Coscinodiscus granii	13.22	13.39	0.55	0.3	0.65	78.51
Ceratium furca	9.15	18.09	0.54	0.31	0.63	79.14
Rhizosolenia stolterfothii	7.46	36.24	0.52	0.31	0.6	79.74
Cyclotell striata	11.24	16.53	0.51	0.32	0.6	80.34
Ceratium tripos	15.76	9.68	0.49	0.33	0.58	80.91
Dictyocha fibula	0.07	25.31	0.48	0.43	0.56	81.84
Chaetoceros atlanticum	0	220.6	0.47	0.19	0.55	82.03
Scrippsiella trochoidea	10.29	9.11	0.45	0.27	0.53	82.56
Ceratium fusus	8.68	13.99	0.45	0.4	0.53	83.08
Coscinodiscus lineatus	2.4	16.99	0.42	0.25	0.49	83.57
Oscillatoria thiebautii	10.01	4.88	0.41	0.22	0.48	84.05
Nitzschia pungens	28.76	0	0.4	0.22	0.47	85.53
Amphora asterearia	5.75	15.22	0.38	0.24	0.45	84.97
Amphisolenia palmata	0	14.27	0.37	0.19	0.44	85.41
Prorocentrum lima	13.79	14.55	0.36	0.31	0.42	85.83
Diploneis splendida	13.04	0.14	0.35	0.08	0.41	86.24
prorocentrum sigmoidess	42.38	0	0.34	0.16	0.4	86.64

Table 2: Contd.,

Pleurosigma acutum	1.68	22.03	0.32	0.21	0.37	87.01
Rhizosolenia imbricata	0	25.74	0.3	0.2	0.39	87.36
Chaetoceros didymus	0	206.8	0.3	0.13	0.35	87.72
Pyrophacus steini	10.74	7.54	0.3	0.32	0.35	88.07
Scrippsiella stinii	22.01	1.28	0.3	0.32	0.35	88.42
Guinardia flaccida	0	19.88	0.29	0.22	0.34	88.76
Rhizosolenia styliformis	0.33	13.15	0.29	0.24	0.34	89.1
Rhizosolenia setigera	2	18.22	0.28	0.21	0.32	89.42
Pseudonitzchia fraudulenta	13.27	3.09	0.27	0.18	0.32	89.74
Navicula gastrum	0.51	13.1	0.27	0.27	0.31	90.05

Phytoplankton Community Structure at Different Transects during the Pre and Post-Monsoon Season

Dinophyceae was the dominant group among the 10 transects during the pre-monsoon season (Figure 4). However, in the post-monsoon season, Bacillariophyceae was the most abundant among the 10 transects. In transect 1 (Strait of Hormuz), Dinophyceae was more abundant than Bacillariophyceae (Figure 5). The non-parametric Kruskal–Wallis test showed significant differences among the transects ($p<0.05$). ANOSIM showed significant differences in phytoplankton compositions among the different transects during the pre- and post-monsoon seasons (global $R = 0.28$ for pre-monsoon and $R = 0.18$ for post-monsoon). During the post-monsoon season, transect 8 (T8) was different from other transects because some genus of Bacillariophyceae, such as *Nitzschia seriata*, *Nitzschia closterium*, *Chaetoceros dichaeta*, *Lauderia annulata*, *Navicula membrane*, *Navicula elegans*, *Navicula gastrum*, *Rhizosolenia imbricata and Lioloma elengatum*, were higher in density compared with other transects.

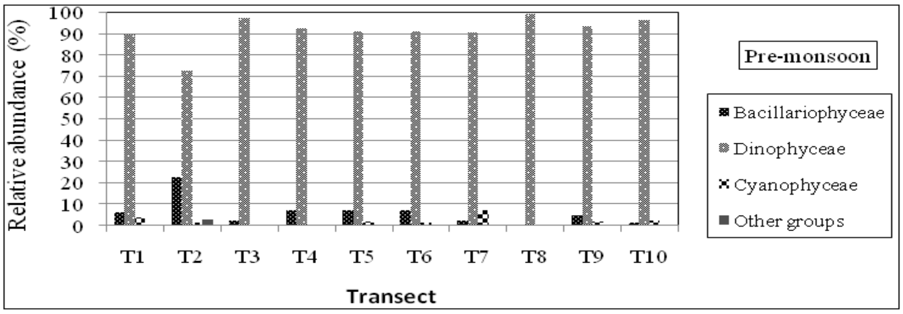

Figure 4: Relative Abundance (%) of Different Groups of Phytoplankton among Transects during the Pre-Monsoon Season 2010

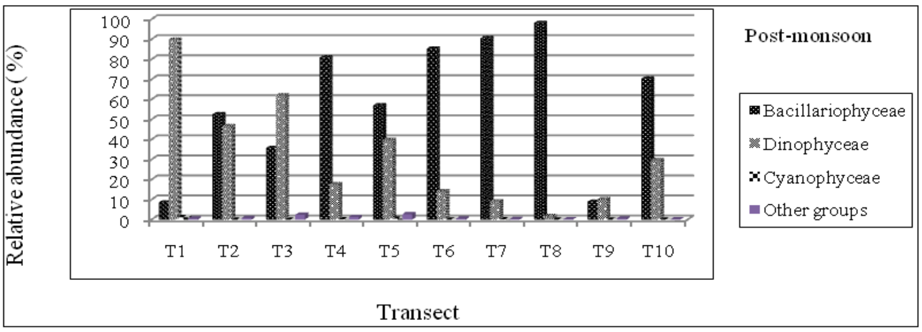

Figure 5: Relative Abundance (%) of Different Groups of Phytoplankton among Transects during the Post-Monsoon Season 2010

Furthermore, according to Bray–Curtis similarity, two main clusters were observed in the pre-monsoon season. Meanwhile, in the post-monsoon season, two main clusters were observed, where one cluster was divided to two sub-clusters, which helped in determining the similarities and differences among the transects (Figure 6).

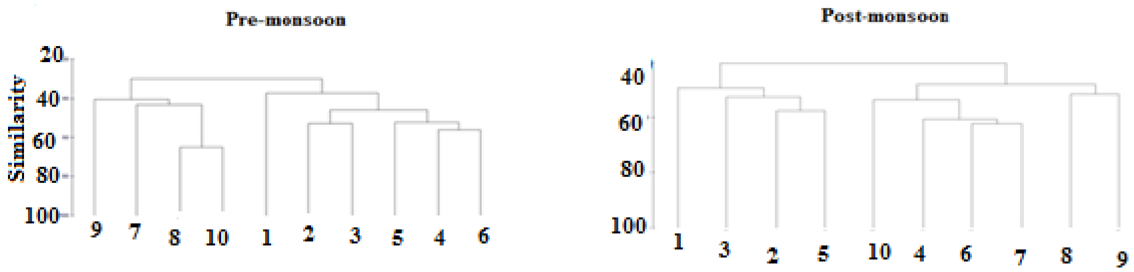

Figure 6: Bray- Curtis Similarity Dendrogram among Transects during the Pre and Post- Monsoon Season

DISCUSSIONS

Analysis of phytoplankton composition is useful in determining the degrees of fertilization among different seasons (Paul *et al*., 2007). Phytoplankton composition and density varied from coast to coast, sea to sea, season to season, and year to year (Prabhahar *et al*., 2011).

The results of this study indicated that the monsoon season is integral in increasing the numbers of phytoplankton, in their distribution, and in their species composition. For example, in the post-monsoon season, higher density of phytoplankton was observed. The reason for this finding was that in the post-monsoon season, density was higher and the phytoplankton community changed. The same result was obtained by Boonyapiwat (1997) in the Gulf of Thailand during the post-monsoon season in 1996.

Naik *et al*. (2009) studied the east coast of India during 2004 and 2005, and found higher phytoplankton density in the post-monsoon season. In the present study, high density was observed in the post-monsoon season and Bacillariophyceae was dominant in the first group. Whereas, high abundance of Dinophyceae was noted in the pre-monsoon season. The results of Saravanakumar et al. (2008) and Ghosh et al. (2012) are in good agreement with the findings of our study, that is, the maximum number of Dinophyceae was observed in the pre-monsoon season.

Chandy et al. (1991) reported that the percentage of Bacillariophyceae was more than that of Dinophyceae in the AL-Jubail area (Persian Gulf); Dorgham *et al*. (1987) found the same results. This finding contradicts our observation in the present study.

At the Nethravathi estuary, blue green algae were frequently found during the pre-monsoon season; in addition, these algae were less abundant during the pre-monsoon season than in the post-monsoon season (Gowda *et al*., 2001), which is in agreement with the results of the present study. Cyanophyceae were found to grow at slightly alkaline conditions and higher temperature; however, normal blooms occurred during the pre-monsoon and summer seasons (Kumar and Sahu, 2012), which is in agreement with our findings. More species were observed during the pre-monsoon season; conversely, in the post-monsoon season, the density was very high.

Cyanophyceae and Dinophyceae were more abundant in the pre-monsoon season, which is in agreement with our findings. D’Costa et al. (2008) found that Dinophyceae were more diverse and dense in the pre-monsoon season compared with the post-monsoon season; however, in the present study more species and higher density of Dinophyceae were observed in the pre-monsoon season. *Nitzschia seriata* was dominant in the phytoplankton community in inshore locations

(Jyothibabu *et al*., 2008). The high abundance of *Nitzschia seriata* in coastal waters and estuary (Cochin) had been reported by Sawant and Madhpratap (1996), Menon et al. (2000), and Madhu *et al*. (2007), correlating with the present results. *Navicula*, *Rhizosolenia*, *Chaetoceros,* and *Nitzschia* populations were low, according to the findings of Abdul Azis *et al*. (2003) in Saudi Arabia (Al-Jubail), which is in contrast with the result of the present study.

Boonyapiwat et al. (2008) conducted a survey on Bengal Bay, and reported that low densities of *Lioloma delicatum* can be found within the area. In the present study, this genus distribution was more prominent in all areas of the study during the post-monsoon season, especially in the eastern parts. However, this genus has never been reported in the Oman Sea. Sanilkumar (2009) conducted a study in Bengal Bay from 2003 to 2004, and found that *Lioloma elongatum* and *Lioloma pacificum* were present but were not given much importance. The summer monsoon caused fertilization in the Oman Sea waters because this season coincided with heavy rainfall, sea turbulence, and high nutrient availability from the bottom to the surface, which provided favorable conditions for phytoplankton growth. In particular, the eastern part of the Oman Sea was affected more by these factors compared with the western part. These findings were clearly observed in the present study.

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